



UNIVERSITI PUTRA MALAYSIA

**PEDOGENESIS AND CLASSIFICATION OF SOILS IN
BANTEN, WEST JAVA, INDONESIA**

ACHMAD FAUZI ISA

FP 2002 29

**PEDOGENESIS AND CLASSIFICATION OF SOILS IN
BANTEN, WEST JAVA, INDONESIA**

ACHMAD FAUZI ISA

**DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA**

2002



**PEDOGENESIS AND CLASSIFICATION OF SOILS IN
BANTEN, WEST JAVA, INDONESIA**

By

ACHMAD FAUZI ISA

**Thesis Submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfillment of the Requirement for
the Degree of Doctor of Philosophy**

June 2002



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

**PEDOGENESIS AND CLASSIFICATION OF SOILS IN BANTEN,
WEST JAVA, INDONESIA**

By

ACHMAD FAUZI ISA

June 2002

Chairman : Associate Professor, Dr Siti Zaayah Darus

Faculty : Agriculture

Co-chairman : Prof. Dr Georges Stoops

Faculty : Science, Ghent University, Belgium

Soils on three toposequences in Anyer, Carita and Saketi areas in Banten Province, West Java, and soil on Rakata island (Krakatau volcano) in Sunda Strait, Indonesia have been sampled for pedogenetic study and classification. The soils in Banten developed on the slope of the Quaternary volcanic complex and the sedimentary facies with different annual rainfall and vegetation. The objectives of this study were to determine the soil physical, chemical, mineralogical and micromorphological properties, to study the genesis of the soils, to determine the effects of the Krakatau ash and to classify the soils according to Soil Taxonomy and World Reference Base.

The results showed that all the soils on the slope of volcanic complex have been strongly weathered to form yellowish brown to red deep soils with high clay content, low pH, low base and various CEC. Mineralogical characteristics of these soils consist of dominant kaolinite in the clay fractions, cristobalite and quartz in the silt fractions and opaque minerals in the sand fractions. The mineralogical characteristics indicate that most of the soils may be formed from andesitic volcanic ash. The

relative higher amount of weatherable minerals with pumice in the surface horizon confirmed that the soils were rejuvenated by fresh volcanic ash from the eruption of Krakatau volcano in 1883. The effects of the Krakatau ash were not shown at the soils on the lower slope of the Saketi toposequence. These soils developed from sedimentary facies which were comprised of acid tuff, claystone and sandstone. These soils are characterised by yellowish brown colour, clay textured B horizons with various sand content with depth, low pH, low base and various CEC.

Pedogenesis processes of these soils were strongly influenced by the parent material, climate and vegetation. Clay illuviation was more evident in the Anyer soils where rainfall is lower compared to Carita and Saketi Soils. In contrast, pedoturbation and homogenisation increase with the wetter climate and forest vegetation in Carita and Saketi. Soils on sedimentary facies in Saketi consist of relatively high quartz sand fraction and more yellow colour than the soils on andesitic volcanic ash. The addition of Krakatau ash in 1883 has caused an increase in exchangeable bases, sand and silt fractions especially in Anyer and higher amount of amorphous materials in the soils at higher elevation of Saketi toposequence. Soils in Anyer were classified as Typic Paleudults according to Soil Taxonomy (Soil Survey Staff, 1999) or Abruptic Acrisols according to World Reference Base (ISSS-ISRIC-FAO, 1998). While in Saketi, the soils which developed on sedimentary facies were classified as Typic Paleudults, but as Profondic Acrisols or Luvisols according to the World Reference Base. Volcanic soils under forest at the lower elevation in Carita can be classified as Andic Tropudults or Humic Acrisols and as Andic Dystrudepts at the higher elevation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEDOGENESIS DAN PENGELASAN TANAH TANAH DI BANTEN,
JAWA BARAT, INDONESIA**

oleh

ACHMAD FAUZI ISA

June 2002

Pengurus : **Profesor Madya Dr Siti Zaayah Darus**

Fakulti : **Pertanian**

Pengurus Bersama : **Prof. Dr Georges Stoops**

Fakulti : **Science, Ghent University, Belgium**

Satu kajian ke atas tanah-tanah di tiga toposekuens di kawasan Anyer, Carita dan Saketi di Banten Province, Jawa Barat, dan ke atas tanah di Pulau Rakata (Gunung berapi Krakatau) di Selat Sunda, Indonesia telah diambil contohnya untuk penyelidikan pedogenetik dan pengelasan. Tanah-tanah ini telah terbentuk atas cerun kompleks Kuaterner gunung berapi dan fasis endapan yang menerima curahan hujan yang berlainan dan berbeza tumbuhan. Objektif kajian ini ialah untuk menentukan sifat fizik, kimia, mineralogi dan mikromorfologi, mengkaji genesis tanah-tanah ini, mengenalpasti pengaruh bahan abu Krakatau ke atas sifat tanah dan mengelaskan tanah ini mengikut system pengelasan 'Soil Taxonomy' dan 'World Reference Base'

Kajian ini telah menunjukkan bahawa semua tanah atas cerun kompleks Kuaterner gunung berapi telah terluluhawa membentuk tanah dalam berwarna coklat kekuningan sampai merah dengan kandungan lempung tinggi, pH yang rendah, bes bertukarganti rendah dan KPK julat bervariasi. Sifat-sifat mineral pada tanah-tanah ini menunjukkan

bahawa kebanyakan tanah-tanah ini terbentuk daripada abu vulkanik andesit. Banyak mineral yang senang terluluhawa dengan pumis dalam horison atas dapat dipastikan bahawa tanah-tanah ini telah menerima bahan abu daripada letusan gunung berapi Krakatau pada tahun 1883. Kesan-kesan daripada abu Krakatau tak ditunjukkan pada tanah-tanah atas cerun bawah Saketi toposekuen. Tanah-tanah ini berkembang daripada fasis endapan yang mengandungi tuf masam, batu lempung dan batu pasir. Tanah-tanah ini dicirikan oleh warna coklat kekuningan, horison B bertekstur lempung dengan variasi kandungan peringkat pasir, pH rendah, base bertukarganti rendah dan variasi KPK julat.

Proses-proses pedogenesis sangat dipengaruhi oleh bahan induk, iklim and tumbuh-tumbuhan. Iluviasi lempung lebih jelas ternampak pada tanah Anyer di mana curahan hujan lebih rendah daripada di kawasan Carita dan Saketi. Sebaliknya pula, gangguan tanah meningkat di kawasan yang lebih lembab dan di hutan seperti di Carita dan Saketi. Penambahan abu vulkanik daripada letusan Krakatau pada 1883 telah meningkatkan bes tukarganti, kandungan pasir dan kelodak terutama sekali di Anyer. Kandungan bahan amorfus pula meningkat pada tanah di kawasan tinggi di Saketi. Tanah-tanah di Anyer dikelaskan *Typic Paleudults* mengikut “Soil Taxonomy” (Soil Survey Staff, 1999) atau *Abruptic Acrisols* mengikut “World Reference Base” (ISSS-ISRIC-FAO, 1998). Tanah-tanah daripada fasis endapan di Saketi juga dikelaskan sebagai *Typic Paleudults*, tetapi sebagai *Profondic Acrisols* atau *Luvic Acrisols* mengikut “World Reference Base”. Tanah-tanah vulkanik di kawasan rendah hutan Carita dikelaskan sebagai *Andic Kandudults* atau *Humic Acrisols* dan sebagai *Andic Dystropepts* atau *Chromic Cambisols* di kawasan tinggi.

ACKNOWLEDGEMENTS

I wish to express my deep gratitude to my promoter, Prof Dr G STOOPS Co-ordinator of the project PhD Training for SE-Asian Soil Scientists and Head of Department of Geology and Soil Science, Ghent University, Belgium for accepting me as a PhD student, accommodating and guiding me, especially during a study visit at Gent University

I am also grateful to Assoc Prof Dr SITI ZAUZYAH DARUS, Head of Department of Land Management, Agriculture Faculty, Universiti Putra Malaysia (UPM) for supervising me as a Ph D student and guiding me from the beginning to the last step of this study Without her constant help, this study would not have been possible

I also wish to acknowledge Prof Dr SHAMSHUDDIN JUSOP and Dr CHE FAUZIAH ISHAK in the Department of Land Management, Agriculture Faculty, UPM for the helpful comments, suggestions, and assistance during my study in UPM, Malaysia

I am also very thankful to the staff of the laboratories of Mineralogy and Micropedology in Department of Land Management, UPM who have kindly introduced me to the various laboratory procedures and techniques that made all my laboratory work much easier

Many thanks goes to Prof Dr E VAN RANST in Department of Geology and Soil Science, Ghent University, for his help in the mineralogical analysis by XRD technique I am also very thankful to the staff in the Mineralogy, Petrology, and Micropedology Laboratories, who have kindly introduced me to the laboratory procedures and techniques that made my laboratory work much easier

Finally, my sincere gratitude to Dr ABDURACHMAN ADI, Director of Center of Soil and Agroclimate Research, Bogor, Indonesia and his staff for their support and assistance during the fieldwork and laboratory analyses in Bogor, Indonesia

I certify that an Examination Committee met on 13th June 2002 to conduct the final examination of Achmad Fauzi Isa on his Doctor of Philosophy thesis entitled "Pedogenesis and Classification of Soils in Banten, West Java, Indonesia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

HAMDAN JOL, Ph.D.

Associate Professor,
Faculty of Agriculture,
Universiti Putra Malaysia
(Chairman)

SITI ZAUYAH DARUS, Ph.D.

Associate Professor,
Faculty of Agriculture,
Universiti Putra Malaysia
(Member)

GEORGES STOOPS, Ph.D.

Professor,
Faculty of Science,
Ghent University
(Member)

SHAMSHUDDIN JUSOP, Ph.D.

Professor,
Faculty of Agriculture,
Universiti Putra Malaysia
(Member)

CHE FAUZIAH ISHAK, Ph.D.

Faculty of Agriculture,
Universiti Putra Malaysia
(Member)

ANIZAN ISAHAK, Ph.D.

Associate Professor,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia
(Independent Examiner)



SHAMSHER MOHAMAD RAMADILI, Ph.D.

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: **24** AUG 2002

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

SITI ZAUYAH DARUS, Ph.D.

Associate Professor,
Faculty of Agriculture,
Universiti Putra Malaysia
(Chairman)

SHAMSHUDDIN JUSOP, Ph.D.

Professor,
Faculty of Agriculture,
Universiti Putra Malaysia
(Member)

CHE FAUZIAH ISHAK, Ph.D.

Faculty of Agriculture,
Universiti Putra Malaysia
(Member)

GEORGES STOOPS, Ph.D.

Professor,
Faculty of Science,
Ghent University
(Member)

AINI IDERIS, Ph.D.

Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



ACHMAD FAUZI ISA

Date: 24 AUG 2002

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL	vii
DECLARATION	ix
LIST OF TABLES	xiii
LIST OF FIGURES	xvii

CHAPTER

1	INTRODUCTION	1.1
2	LITERATURE REVIEW	2.1
	2.1 Soil Forming Processes	2.1
	2.1.1 Soil Physical Processes	2.2
	2.1.2 Soil Chemical Processes	2.4
	2.1.3 Soil Biological Processes	2.9
	2.1.4 Weathering Profile and Pedogenesis Processes	2.10
	2.2 Morphology and Properties of Volcanic Soils	2.16
	2.2.1 Morphology	2.17
	2.2.2 Physical Properties	2.20
	2.2.3 Chemical Properties	2.20
	2.2.4 Mineralogical Properties	2.24
	2.2.5 Micromorphological Properties	2.28
	2.3 Classification of Volcanic Soils	2.28
	2.3.1 Soil Classification According to Soil Taxonomy	2.33
	2.3.2 Soil Classification According to World Reference Base	
	2.3.3 Soil Classification According to Indonesian Soil Classification	2.35
	2.4 Volcanic Activities and Soils in Indonesia	2.36
	2.4.1 Volcanic Activities	2.36
	2.4.2 Volcanic Soils in Indonesia	2.38
	2.4.3 Parent Materials and Soils in Banten, West Java	2.40
3	DESCRIPTION OF THE STUDY AREA	3.1
	3.1 Location	3.1
	3.2 Geology and Geomorphology of the Study Area	3.3
	3.2.1 Geology	3.3
	3.2.2 Geomorphology	3.5
	3.2.3 The 1883 Krakatau Ash Deposits	3.6
	3.3 Climate	3.7
	3.3.1 Rainfall	3.7

3.3.2	Temperature and Potential Evapotranspiration	3.8
3.3.3	Classification of Climate	3.11
3.4	Soil Types	3.13
3.5	Vegetation and Land use	3.14
4	MATERIALS AND METHODS	4.1
4.1	Field Methods	4.1
4.1.1	Surveyed Areas and Soil Sites	4.1
4.1.2	Soil Samples	4.4
4.2	Laboratory Methods	4.5
4.2.1	Chemical Analysis	4.5
4.2.2	Physical Analysis	4.9
4.2.3	Mineralogical Analysis	4.12
4.2.4	Micromorphological Analysis	4.14
5	PEDOGENESIS AND CLASSIFICATION OF SOILS OF THE ANYER TOPOSEQUENCE	5.1
5.1	Soil Properties	5.1
5.1.1	Morphological Properties of Soil Profiles	5.1
5.1.2	Physical Properties	5.5
5.1.3	Chemical Properties	5.8
5.1.4	Mineralogical Properties	5.10
5.1.5	Micromorphological Properties	5.25
5.1.6	Discussion	5.31
5.2	Pedogenesis of the Studied Soils	5.33
5.2.1	Soil Forming Factors and Processes	5.33
5.2.2	Effects of the 1883's Krakatau Ash	5.36
5.2.3	Discussion	5.39
5.3	Soil Classification	5.40
5.3.1	Soil Classification According to Soil Taxonomy	5.40
5.3.2	Soil Classification According to World Reference Base ..	5.43
5.3.3	Soil Classification According to Indonesian Soil Classification	5.44
5.3.4	Discussion	5.45
6	PEDOGENESIS AND CLASSIFICATION OF SOILS OF THE CARITA TOPOSEQUENCE	6.1
6.1	Soil Properties	6.1
6.1.1	Morphological Properties of Soil Profiles	6.1
6.1.2	Physical Properties	6.4
6.1.3	Chemical Properties	6.7
6.1.4	Mineralogical Properties	6.8
6.1.5	Micromorphological Properties	6.19
6.1.6	Discussion	6.26
6.2	Pedogenesis of the Studied Soils	6.28
6.2.1	Soil Forming Factors and Processes	6.28
6.2.2	Effects of the 1883's Krakatau Ash	6.31
6.2.3	Discussion	6.33
6.3	Soil Classification	6.34
6.3.1	Soil Classification According to Soil Taxonomy	6.34

6.3.2	Soil Classification According to World Reference Base ..	6.37
6.3.3	Soil Classification According to Indonesian Soil Classification	6.39
6.3.4	Discussion	6.40
7	PEDOGENESIS AND CLASSIFICATION OF SOILS OF THE SAKETI TOPOSEQUENCE	7.1
7.1	Soil Properties	7.1
7.1.1	Morphological Properties of Soil Profiles	7.1
7.1.2	Physical Properties	7.5
7.1.3	Chemical Properties	7.8
7.1.4	Mineralogical Properties	7.10
7.1.5	Micromorphological Properties	7.21
7.1.6	Discussion	7.29
7.2	Pedogenesis of the Studied Soils	7.31
7.2.1	Weathering of Minerals	7.31
7.2.2	Clay Illuviation	7.33
7.2.3	Biology Activities	7.33
7.3	Soil Classification	7.35
7.3.1	Soil Classification According to Soil Taxonomy	7.35
7.3.2	Soil Classification According to World Reference Base ..	7.37
7.3.3	Soil Classification According to Indonesian Soil Classification	7.39
7.3.4	Discussion	7.40
8	GENERAL DISCUSSION	8.1
8.1	Soil Morphology	8.1
8.2	Physical Properties	8.2
8.3	Chemical Properties	8.4
8.4	Mineralogy	8.10
8.5	The Effects of Krakatau Ash	8.11
8.6	Weathering Index	8.12
8.7	Micromorphology	8.14
8.8	Soil Classification	8.15
8.9	Recommendation for Management of the Soils	8.17
9	CONCLUSIONS	9.11
	REFERENCES	R.1
	APPENDICES	
	A Profile Description and Laboratory Data of Anyer Soils	A. 1
	B Profile Description and Laboratory Data of Carita Soils	A.10
	C Profile Description and Laboratory Data of Saketi Soils	A.19
	D Profile Description and Laboratory Data of Soils on the Krakatau Volcano (Rakata Island)	A.31
	E Land Evaluation of the Profile Data	A 34

LIST OF TABLES

Table	Page
2.1 Weathering product of some minerals	2.6
2.2 The distribution and possible ages of the calderas along the Indonesian volcanic belt (Katili, 1983)	2.38
3.1 Chemical composition of pumice clast from the 1883's Krakatau eruption	3.7
3.2 Average monthly rainfall (mm) in the study area	3.8
3.3 Monthly temperature (T), rainfall (R), and potential evapotranspiration (PET) at Serang	3.9
3.4 Rainfall and climate types of the study area (Schmidt and Ferguson, 1951)	3.11
4.1 Number of soil profiles and soil samples from the study locations ...	4.4
5.1 Morphological properties of the studied soils on Anyer toposequence	5.3
5.2 Particle-size distribution and textural classes of the studied soils of the Anyer toposequence	5.5
5.3 Some physical properties of soils of Anyer toposequence	5.7
5.4 Soil pH, organic carbon, exchangeable Al and bases, CEC, and effective CEC of soils in Anyer, Banten	5.8
5.5 Mineralogical composition of the total sand fractions of the Anyer soils	5.10
5.6 Mineralogical composition of silt fractions in Anyer soils as identified by XRD analysis	5.15
5.7 Mineralogical composition of the clay fractions in Anyer soils as identified by XRD analysis	5.22
5.8 Micromorphological features of profile A1 and A2	5.26
5.9 Micromorphological features of profile A3	5.27
5.10 The ratio of silt, Fe_o/Fe_d and effective CEC in relation to the elevation	5.34
5.11 Soil properties on the Rakata island and the Anyer toposequence	5.39

5 12	Evaluation of soil properties for determination of mollic, umbric and ochric epipedon	5 40
5 13	Evaluation of soil properties for determination of a cambic, an argillic and a kandic horizon	5 41
5 14	Diagnostic horizons and classification of Anyer soils	5 42
5 15	Diagnostic horizons of the studied soils	5 43
5 16	Soil groups and lower level units of the studied soils in WRB classification (FAO, 1998)	5 44
5 17	Soil groups and lower level unit of the studied soils in Indonesian soil classification (Suhardjo <i>et al</i> , 1983)	5 45
5 18	Classification of the the profiles in Banten area according to Soil Taxonomy, World Reference Base and National Classification	5 46
6 1	Morphological properties of soils on Carita toposequence	6 3
6 2	Particle-size distribution and textural classes of the studied soils of the Carita toposequence	6 5
6 3	Physical analysis of studied soils of Carita toposequence	6 6
6 4	The chemical data of pH, organic carbon, exchangeable Al and bases, CEC, and effective CEC of soils in Carita, Banten	6 8
6 5	Mineralogical composition of the sand fractions of the Carita soils	6 9
6 6	The relative abundance of minerals in the silt fractions of each profile on Carita toposequence as identified by XRD analysis	6 11
6 7	Relative abundance of minerals in the untreated clay fractions of Carita soils as identified by XRD analysis	6 17
6 8	Micromorphological features of profile C1 in Carita	6 22
6 9	Micromorphological features of profile C2 in Carita	6 23
6 10	Micromorphological features of profile C3 in Carita	6 24
6 11	The ratio of silt to clay, Fe _o to Fe _d and Fe ₂ O ₃ to silt and Fe ₂ O ₃ to clay in Carita soils	6 30
6 12	Comparison of some properties of Rakata and Carita soils	6 32
6 13	Evaluation of soil properties for determination of a mollic, an umbric and an ochric epipedon	6 35

6.14	Evaluation of soil properties for determination of a cambic, an argillic and a kandic horizon	6.35
6.15	Diagnostic horizons and classification of Carita soils in the groups and family levels	6.37
6.16	Diagnostic horizons of the studied soils	6.38
6.17	Soil groups and lower level units of the studied soils in WRB classification (ISSS-ISRIC-FAO, 1998)	6.39
6.18	Soil groups and lower level units of the studied soils according to the national soil classification (Suhardjo <i>et al.</i> , 1983)	6.39
6.19	Classification of the three profiles in Carita according to Soil Taxonomy, World Reference Base and National Classification	6.40
7.1	Morphological properties of Saketi soils, Banten	7.3
7.2	The particle-size distribution and textural classes of the studied soils of the Saketi toposequence	7.6
7.3	The physical analysis in the studied soils	7.7
7.4	The chemical properties of the studied soils in Saketi	7.9
7.5	Acid oxalate and DCB extractable Fe and Al of each soil	7.10
7.6	Mineralogical composition of the sand fractions	7.11
7.7	Relative abundance of minerals in the silt fractions of Saketi soils as identified by XRD analysis	7.12
7.8	Mineralogical composition of the clay fractions in Saketi soils as identified by XRD analysis	7.19
7.9	Micromorphological features of profile S1	7.22
7.10	Micromorphological features of profile S2	7.24
7.11	Micromorphological features of profile S3 and S4	7.27
7.12	Evaluation of soil properties for determination of a mollic, an umbric and an ochric epipedon	7.35
7.13	Evaluation of soil properties for determination of subsurface diagnostic horizons	7.36
7.14	Diagnostic horizons and classification of Saketi soils	7.37

7.15	Diagnostic horizons of the studied soils	7.38
7.16	Soil groups and lower level units of the studied soils in WRB classification (ISSS-ISRIC-FAO, 1998)	7.39
7.17	Soil groups and lower level units of the studied soils in Indonesian soil classification (Suhardjo <i>et al.</i> , 1983)	7.40
7.18	Classification of the three profiles in Saketi according to Soil Taxonomy, World Reference Base and National Classification	7.41
8.1	Chemical properties of the volcanic soils in Banten	8.4
8.2	The weathering index of each soils	8.12
8.3	General micromorphology of the soils in Banten	8.13
8.4	Classification of the profiles in Banten area according to Soil Taxonomy, World Reference Base and National Classification	8.15
8.5	Land suitability classes for some agricultural crops in the study area	8.18

LIST OF FIGURES

Figure	Page
2.1 Formation and transformation of clay minerals and their organic complexes in soils derived from volcanic ash in udic, temperate climate	2.22
2.2 Distribution of caldera and creater forms in Indonesian archipelago	2.37
3.1 Location of the study area in Banten Province on the west of Java, Indonesia	3.2
3.2 Geological map of Banten	3.4
3.3 Potential evapotranspiration (PET) and rainfalls of Serang (Rs) and Anyer (Ra)	3.10
3.4 Potential evapotranspiration (PET) and rainfalls of Labuan (RI) and Menes (Rm)	3.10
4.1 A broad outline of the pedogenetic study in Banten Province	4.2
4.2 Location of the selected toposequences (A=Anyer; C=Carita; S=Saketi) on the slope of volcanic complex in Banten	4.3
5.1 A schematic representation of soil sites and profile morphology on Anyer toposequence	5.2
5.2 XRD of silt fractions from the Ap and Bt2 horizons of profile A1...	5.13
5.3 XRD of silt fractions from the Bt2 horizons of profile A2 and A3...	5.14
5.4 XRD pattern of the untreated clay of profile A1	5.17
5.5 XRD pattern of the untreated clay of profile A2	5.18
5.6 XRD pattern of the untreated clay of profile A3	5.19
5.7 XRD of clay fractions after DCB treatment in the Bt2 horizons of Profiles A1 (a), A2 (b) and A3 (c)	5.20
5.8 The XRD pattern of the selected clay in heating treatments	5.21
5.9 DTA and TG of a clay sample of the Bt3 horizon of profile A3	5.23
5.10 SEM of a clod surface from the Bt2 horizon of profile A3 shows platy and crumpled layers of kaolinite (a) and fine halloysite (b)	5.24

5.11	The micrographs of profiles A1 show: (a) Pumice fragments (Pm) and opaque minerals (Op) in the Ap horizon; (b) Root section with excrement and clay coatings in the Bt2 horizon; (c) Clay coatings on planar voids and rock fragments in Bt3 horizon	5.28
5.12	Micrographs of profiles A2 and A3 show: (a) Clay coatings and partially stressed deformed in the Bt2 of profile A2; (b) Pumice fragments (Pm) and opaque minerals (Op) in the Ap horizon of profile A2; (c) Clay coatings of planar voids and vughs in the Bt2 of profile A3	5.29
5.13	SEM of the coarse grains and the clod surface of profile A3 shows (a pumice grains in the surface horizon; (b) weathered minerals (wm) and mineral grains in the Bt2 horizon; and (c) clay coatings on clod surface of the Bt2	5.32
5.14	Distribution of total clay and fine clay	5.35
5.15	(a) The 1883's pumiceous tuff deposits on Rakata island, the remnant of Krakatau volcano; (b) a thin soil on the pumiceous tuffs; (c) the micrograph of pumiceous tuffs shows dominant glass and some hypersthene, plagioclase and opaque minerals, PPL and XPL (d); (e) The SEM of the silt fractions shows elongated and vesicular glass; and (f) the sand fractions of the pumiceous tuffs consist of vesicular rounded, elongated and curve forms of glass and crystall minerals in the sand fractions	5.38
6.1	Schematic representation of soil sites and profile morphology on Carita toposequence	6.2
6.2	XRD pattern of silt fractions of profiles C1 and C3	6.12
6.3	XRD pattern of the untreated clay of the profile C1	6.13
6.4	XRD pattern of the untreated clay of the profile C2	6.14
6.5	XRD pattern of the untreated clay of the profile C3	6.15
6.6	XRD pattern of the treated clay from Ah horizon of profile C3	6.16
6.7	DTA and TG curve of the clay fraction of the Bt2 horizon profile C1...	6.18
6.8	(a) and (b) Euhedral plagioclase (Pl) and pyroxene (Py) phenocrysts and grayish dotted glass groundmass with fine grains of plagioclase and iron oxides; (c) and (d) Alteration of plagioclase and hypersthene (Hy) to clay and amorphous materials; and (e) and (f) Alteration of plagioclase-feldspar (F) to clay and of olivine (O) to crystalline clay and amorphous materials	6.20

6.9	Micromorphological properties of Carita soils show: (a) Crumb and granular microstructures in the Bt2 of profile C1; (b) Dense infillings of channels and saprolite in the Bt2 of profile C2; (c) Saprolite fragments in the BC of profile C2; (d) Subangular blocky and crumb microstructures in the Bw1 of profile C3; (e) Pumice grains in the Ah horizon of profile C3; (f) Alteration of the rock fragments to yellow and yellowish brown fine materials (f)	6.25
6.10	SEM of the clod surface and coarse materials of the profile C1 shows: (a) Crumb structure with many pores in the surface horizon; (b) The excrements and the cemented aggregates in the surface horizon; (c) The coarse materials in the surface horizon of profile C1 consist of fibrous and curve glass; and (d) The coarse materials in the subsoil horizon show the rounded grains of minerals and pseudosilt	6.27
7.1	Schematic representation of soil sites and profile morphology in Saketi	7.2
7.2	XRD of silt fraction from the Bt2 horizons of profiles S1 and S2	7.13
7.3	XRD of silt fraction from the Bt2 horizons of profiles S3 and S4	7.14
7.4	XRD of the clay fractions from the profile S1 and S2	7.16
7.5	The XRD pattern of the treated clay with Mg^{2+} , Mg^{2+} glycol, K^+ and K^+ 550 °C from the Bt3 horizon of the profile S1	7.17
7.6	XRD of clay fractions from the selected horizon of profiles S3 and S4.....	7.18
7.7	DTA and TG of clay fraction from the surface and subsoil horizon of profile S4	7.20
7.8	(a) and (b) Yellowish brown dotted clay with stipple speckled and grano striated b-fabric, quartz (Qz), mica (mc) and opaque (Op) minerals in the Bt2 horizon of profile C1; (c) and (d) Dark brown speckled clay with undifferentiated b-fabric and granostriated b-fabric on the coarse quartz grains in Bt1 horizon of profile S2; (e) and (f) Yellow limpid clay coatings on channels and yellowish brown speckled clay with stipple speckled and weak porostriated b-fabric in the Bt2 horizon of profile S2	7.25

7.9	(a) Crumb structure in the Ap-Bt1 horizon of profile S3; (b) Crumb structure with occasionally subangular blocky and clay coatings in the Bt3 horizon of profile S3; (c) and (d) Subangular blocky structure with planar voids and vughs in the Bw1 and Bw3 horizons of profile S4; and (e) and (f) Pumice grains (Pm), weathered glass (Wg) and opaque (Op) in the Ap horizon of profile S4.....	7.28
7.10	A pyroxene andesite with agglomeroporphyritic texture consists of euhedral and subhedral phenocrysts of plagioclase (Pl), hypersthene (Py) and iron oxides (Io)	7.30
7.11	Distribution of the ratio of silt to clay and the ratio of Fe_2O_3 to silt in Saketi soils	7.32
7.12	Distribution of clay and fine clay in the Saketi soils	7.34
8.1	Relationship between phosphate retention and Fe_o (A) and phosphate retention and Al_o (B)	8.7
8.2	Relationship between phosphate retention and Fe_d	8.8
8.3	Relationship between CEC-clay and clay content	8.9
8.4	Correlation between dithionitecitrate Fe and CEC-clay	8.9
8.5	Correlation between the silt to clay ratio and the Fe_2O_3 to silt ratio..	8.13

CHAPTER 1

INTRODUCTION

Most soils in the Indonesian archipelago are derived from or influenced by volcanic materials. Therefore the distribution and the type of soils formed in this region is strongly affected by the age and the type of volcanic materials, topographical and climatic conditions. Soils derived from volcanic materials are commonly classified as Andisols according to Soil Taxonomy or Andosols according to World Reference Base. However, some studies of volcanic soils in Indonesia showed that Andisols are mainly found at the higher elevation of the young volcanic area. At the lower elevation or on the older volcanic materials the soils have developed with weak or without andic properties and can be classified into other soil orders, such as Inceptisols, Alfisols, Ultisols, and Oxisols (Buurman *et al.*, 1976; Subardja and Buurman, 1980; Subagjo *et al.*, 1984).

In Indonesia, more than 60% of the agricultural products are the result of agricultural activities on the volcanic soils. The intensification and extensification of agricultural development programs that have been conducted by the government in this country have not only increased agricultural products, but have also brought some problems, such as, soil degradation, soil and water pollution, and other environmental quality problems. A basic understanding of the main soil forming factors and soil forming processes of the volcanic soils can be useful not only for soil classification, but also for investigating the consequences of agricultural activities and other land uses.

Banten, located in West Java, Indonesia consists of soils developed on the Old Quaternary volcanic materials and Pliocene sedimentary facies (Geological Survey of Indonesia, 1963). The soils in this area have been classified as Latosols and Podzolic Soils according to Dudal and Soepraptohardjo (1957). The classification was based on poor and rich parent materials, colour, texture, pH and occasionally on organic matter status. This soil classification has a broad definition and implies that the classified soils can be found on wide areas with various kinds of parent materials. Thus a precise soil classification that is more efficient for land use in this area becomes necessary.

A study of volcanic soils in Banten is still needed as the soils developed on the Quaternary volcanic materials in the northern part of Banten are intensively used for agricultural activities. During the Krakatau eruption in 1883, the area had been affected by the Krakatau ash falls (Verbeek, 1885, Mohr, 1944). However, the effects of the Krakatau ash falls on the soil properties is yet unknown. Therefore, a detailed pedogenetic study on the volcanic soils in Banten becomes very important. The results of this study may help solve the soil classification problems and give a precise guide for the agricultural management.

This study emphasised on the characterisation and pedogenetic aspects of volcanic soils in Banten, West Java, Indonesia. The objectives of this study are

1. To determine the physico-chemical, mineralogical and micromorphological characteristics of volcanic soils in Banten, West Java, Indonesia,
2. To study the genesis of the soils in relation to parent material, topography and climate,

3. To determine the effects of the 1883's Krakatau ash falls on the soil properties;
and
4. To classify the soils according to Soil Taxonomy (Soil Survey Staff, 1999) and the World Reference Base (ISSS-ISRIC-FAO, 1998).